BLOOD PRESSURE ESTIMATION BY PARTICLE SWARM OPTIMIZATION

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Abstract- **Blood pressure has been estimated by different mathematical models. These models depend on variable and constant factors. In addition, some evolutionary techniques were employed to minimize the difference between estimated and measured blood pressure as well as to measure blood pressure continuously. In this paper, the Particle Swarm Optimization (PSO) is used to estimate Mean Arterial blood Pressure (MAP) based on Heart Rate (HR) variability. This model is utilizing 20 cases of MIMIC database [1]. The research results are reliable and accurate, the difference achieved between estimated and real MAP is very small (mean of difference is ±3mmHg).**

***Keywords*- Mean Arterial pressure, Particle swarm optimization, Heart Rate.**

I. INTRODUCTION

Blood pressure irregularity is a symptom of many diseases; such as flu, hypertension, hypotension, diabetes, arterial stiffness and heart attack, therefore, physicians measures blood pressure to diagnose the health situations of patients. Currently, physicians measures blood pressure by two methods:

1- Arterial cannulation method; which depends on blood height (h) in the catheter inserted inside the artery. Then blood pressure of diagnosed subject is estimated through this mathematical model [2]:

$$P = \rho g h \tag{1}$$

Where P is blood pressure,
ρ is blood density,
g is acceleration of gravity
h is blood height.

This method is accurate and reliable, but it is very invasive and causes limb ischemia, thrombosis, hemorrhaged and other bad affects [3].

2- Auscultatory method; which depends on applying external pressure to obstruct blood flow; the blood pressure of diagnosed subject equal the applied external pressure while blood starts flow in squeezed artery [4].

Auscultatory method depends on investigators' experience to hear heart beats and blood flow; while it does not depend on mathematical model. It use external pressure that applied by cuff; which consumes time for inflation and deflation as well as the applied pressure cause uncomfortable situation for subject.

To reduce invasive effect of Arterial cannulation and discontinuity, investigators' experience and non-comfortably of Auscultatory methods, the researchers are developing new techniques depend on different factors, new sensors and techniques to estimate blood pressure continuously, non-invasively, comfortably and need less experience.

One of these new methods depends on Heart rate as a one of factors related to Blood pressure estimation through the mathematical model [5]:

$$MAP = HR \times SV \times TPR \tag{2}$$

Where MAP is mean arterial pressure,
SV is Stroke Volume,
HR is Heart rate,
TPR is Total Peripheral Resistance.

Heart Rate is measured directly by photo-plethysmography (PPG) sensor; where as heart rate equals the frequency of PPG signal. PPG is the output signal of PPG sensor. PPG sensor consists of infrared or red light emitting diode as transmitter and optical-diode as receiver. PPG sensor is attached to diagnosed subject's finger as shown in Fig. 1.

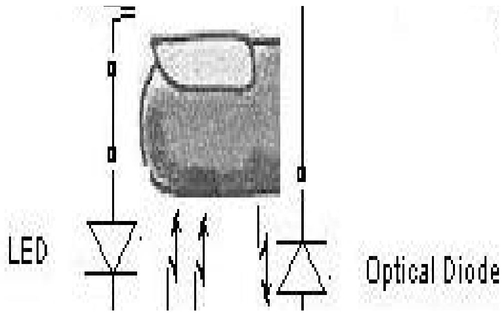

Fig.1. Model circuit of PPG sensor

Measuring blood pressure by this method is continuous and non-invasive; because it depends on PPG sensor; which is attached to diagnosed subject's finger and emits light signal continuously, comfortably and non-invasive.

This paper concerns on developing an evolutionary model which is utilizing Heart rate, as a variable factor, and Particle Swarm Optimization (PSO), as evolutionary technique, to estimate non-invasive, continuous, reliable and accurate blood pressure.

II. PARTICLE SWARM OPTIMIZATION

The Particle Swarm Optimization is new evolutionary technique, which deals with nonlinear, multimode, noisy, non-differentiable research problems. The PSO relays on a certain insight concerning on persons' actions and cognitions [6].

Particle Swarm Optimization fundamentals are population of particles, interconnection topologies, search algorithms and evaluation rules, these fundamentals cooperate to find the optimum solution of problem.

The normal population of PSO is twenty to fifty particles, this number is determined depend on the problem size; however, this population is far less than usual population of other evolutionary algorithms.

PSO particles have interconnection topologies describing the communication among them to move within problem domain to find optimum solution. There are two topologies:

1- Sociometry topology or global best topology; where every particle is connected with all particles of population and influenced by particle which has found best problem solution.

2- Ring lattice or local best topology; where every particle is connected to previous and next particles of the population array only.

Local best topology can converge separately on various optima solutions in problem space and it has fewer connections between particles than global best topology. However, global best topology is faster to find an optimum solution of problem [7].

The main fundamental of PSO is the search algorithms; which change particles' positions through these equations

$$v_d(t+1) = \chi \times v_d(t) + \varphi_1 \times rand \times (p_{i,d} - x_{i,d}(t)) + \varphi_2 \times rand \times (p_{g,d} - x_{i,d}(t)) \quad (3)$$

$$x_d(t+1) = x_d(t) + v_d(t+1) \quad (4)$$

v_d is the displacement of particle's movement
x_d is the particle's position within problem domain
χ is the constriction coefficient
$\varphi_{1,2}$ is the acceleration constants
$p_{i,d}$ is the local best within neighbors particles
$p_{g,d}$ is the global best within all particles

Firstly, Parameters' values of $v_d(1)$, $x_d(1)$, $\varphi_{1,2}$, χ, $p_{i,d}$ and $p_{g,d}$ are initialized to start particles' movements within problem space.

Acceleration constants' values $\varphi_{1,2}$ manage particles' movements and the probability of finding optimum solution slowly with high fineness or quickly with less fineness. In other hand, construction coefficient χ balances between the effect of previous displacement and the effect of interconnection topologies local and global best on current displacement.

Besides these algorithms and their parameters, maximum displacement (Vmax) and maximum position (Xmax) will be located to surround the positions' movement within problem space and stop particle searching out of problem space.

Secondly, particles fly within problem domain by updating their displacements v_d by equation (3) then their positions x_d by equation (4).

Thirdly, the evaluation rules appraise the obtained solution success and assist PSO search algorithms to achieve optimum problem solution by adjusting global $p_{g,d}$ and local $p_{i,d}$ best values according to new particles' positions.

Finally, this operation is reiterated till the search algorithm reached the optimum solution.

In summary, PSO search algorithms and interconnection topologies control the particles' movements within problem domain to find the optimum problem solution, which is evaluated by evaluation rules.

III. Methodology

Practically; the relationship between mean arterial pressure and heart rate is nonlinear [8]; because of many reasons, such as, Stroke Volume changing and Total Peripheral Resistance. Therefore, Particle Swarm Optimization (PSO) is used to deal with this nonlinear research problems.

In previous work [9]; new mathematical model is suggested to consider SV adjustment, which depends on HR. Therefore, the equation (2) has written as:

$$MAP = HR \times SV \times TPR \times (1 + A \times HR) \quad (5)$$

Where A is SV adjustment

In this paper, SV × TPR constant is evaluated through operating PSO on twenty cases' records of MIMIC database from Physio-bank database [1]; which includes continuous records for each case from intensive care unit (ICU) every second over than 10 hours; that means 36000 records for each case, at least. In addition, these records includes signals and interrupted measurements such as HR, MAP, Systolic BP and Diastolic BP for each case; which are measured from a bedside monitor and clinical database extracted from patients' medical records.

SV × TPR value; which was achieved by PSO operation, is substituted in equation (5). Then MAP was estimated by equation (5) for all twenty cases' records of MIMIC database, and then the estimated MAP is compared with real MAP. These results are illustrated in tables and figures as shown in next section.

III. Results

Each case of MIMIC database has 36000 records, at least. To illustrate these results properly, mean of Estimated and Real MAP for all records of each case was calculated and tabled in Table I.

TABLE I
MEANS OF REAL AND ESTIMATED MAP

No. of Cases	Real MAP (mmHg)	Estimated MAP (mmHg)
1	63.3967	75.1143
2	80.0318	80.1915
3	75.3441	66.7069
4	80.8108	71.3428
5	72.9791	73.7322
6	75.2922	75.2916
7	75.6238	79.2474
8	72.2834	75.6739
9	79.4488	69.5596
10	75.6435	70.7586
11	77.6002	78.1561
12	74.2112	78.7500
13	76.8031	74.4961
14	81.1984	80.1399
15	75.3162	77.0265
16	71.248	67.8786
17	71.5802	72.4768
18	69.7526	79.5095
19	84.7407	76.4281
20	72.5393	77.4310

The estimated of MAP is very close to the real MAP; such as real MAP of case 14 = 81.1984 mmHg and estimated MAP of case 14 = 80.13987 mmHg. This means that; the new developed mathematical model is a reliable model. In addition, the implementing of PSO achieved an optimal value for the (SV × TPR) constant; which minimizes the difference between real and estimated MAP, as it is shown in Fig. 2.

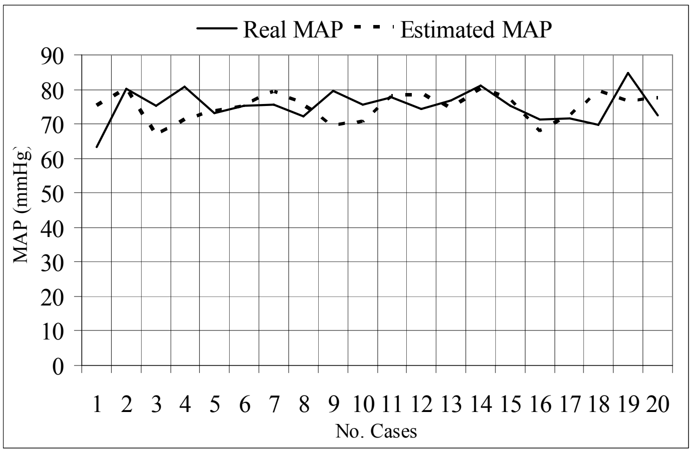

Fig. 2 Means of Real and Estimated Mean Arterial blood Pressure (MAP)

Moreover, the reliability of this model is shown by a sample of one hundred records of case 16 for real and estimated MAP by equation (5) and illustrated in Fig. 3.

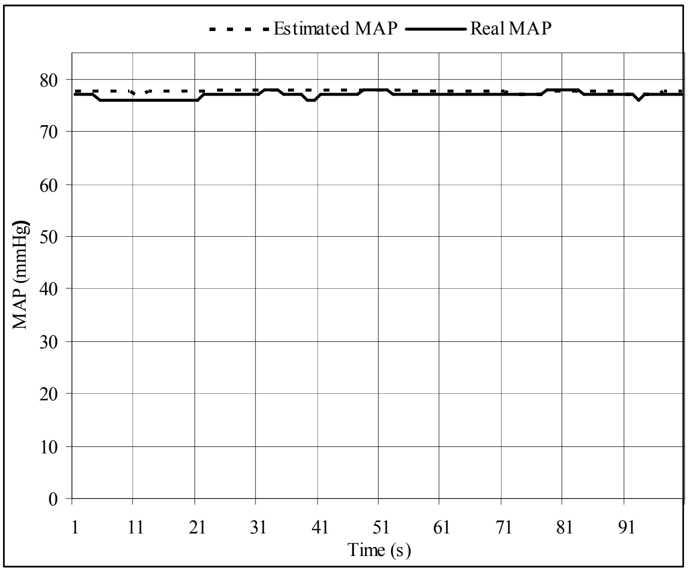

Fig. 3 Sample of case 16 for Real and Estimated Mean Arterial blood Pressure (MAP)

IV. CONCLUSIONS

The relationship between heart rate (HR) and mean arterial pressure (MAP) is nonlinear [8]. In this paper, Particle Swarm Optimization was utilized to process the nonlinearity of MAP and HR relationship and evaluate SV × TPR.

The Estimated MAP by this mathematical model is more reliable and closer to Real MAP as shown in tables and figures.

In addition, Particle Swarm Optimization achieved an optimal value for the (SV × TPR) constant, which minimized the difference between real and estimated MAP.

The work of this paper is part of our project to develop the Cardiovascular Parameters Long Term Monitoring System (CPLTMS).

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